FINAL REPORT

FIRE HISTORY STUDY: ASHLAND DISTRICT, CUSTER NATIONAL FOREST, EASTERN MONTANA

FOR:
Custer National Forest

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INTRODUCTION

Ponderosa pine forests "…are created by dynamic interactions among natural processes, such as fire, and forest structure, such as tree density and canopy openings, across variable landscapes" (Allen et al. 2002, p. 1418). Ecological restoration of ponderosa pine forests requires an appreciation and understanding of the natural variability found in these ecosystems across the West. Fire is especially critical to forest ecosystem development, to maintaining biodiversity, and in the cycling of nutrients. In recent years, the United States Forest Service has emphasized the understanding of natural fire regimes to direct restoration of vegetation systems and fire policies such as prescribed burning programs. Understanding the spatial extent and frequency of fire in pre-EuroAmerican settlement fire regimes is critical for proper management of healthy ecosystems.

Although natural variability, especially in fire regimes, for ponderosa pine is quite well known for the American Southwest (Sneed et al. 2002; Swetnam and Baisan 1996) and, to a lesser extent, in the Northern and Central Rockies (Arno et al. 1995; Bragg et al. 1998), only recently have studies focused on the eastern edge of the species range in Montana, South Dakota, and Wyoming (Brown and Sieg 1996; Morgan et al. 2002; Shinneman and Baker 1997). More specifically, "information is lacking about the historic frequency and spatial pattern of fire occurrences in ponderosa pine and broadleaf forest (green ash, aspen, birch) habitat types of eastern Montana" (SLIC, CNF 2000). Therefore, it was proposed that a pilot study of ponderosa pine fire history be conducted in the Ashland Ranger District (ARD) of the Custer National Forest (CNF) (see Figure 1 for location). To facilitate the objectives of this pilot study, in July of 2003, Prescott

College (PC) entered into a Participating Agreement with the Custer National Forest to carry out historical ecological research, especially fire history, primarily in ponderosa pine forests of the Ashland Ranger District of the CNF. It was anticipated that this pilot study may initiate a multi-year project, which may include greatly expanding the geographic extent of fire history studies in the Ashland Ranger District, extending such studies to the Sioux District, and attempting to reconstruct the fire history of other woody vegetation types (e.g., broadleaf and juniper woodlands) of eastern Montana.

At the time the project started, the fire history of ponderosa pine forests in the northern Great Plains generally, and the Ashland RD in particular, was inadequately known. Because there was such a paucity of information, this pilot project was planned to accomplish the following objectives:

1) Conduct a bibliographic search for existing literature and historic documents containing pertinent information on the pre-EuroAmerican settlement range of natural variation in ponderosa pine in the Ashland Ranger District and other eastern sections of the Custer National Forest.

2) Carry-out a reconnaissance of the ARD to determine the existence and spatial extent of old-growth ponderosa pine as well as fire scarred trees, snags, stumps, and downed logs.

3) Collect increment borer samples from old-growth ponderosa pine to develop a master chronology for eastern Montana to facilitate fire scar dating and climatic reconstruction.

4) Collect a small “judgmental” sample of fire scars to begin development of a fire chronology for ponderosa pine in eastern Montana, especially the Ashland RD.

5) Provide a report on the results of the pilot study, with preliminary assessments of fire history in ponderosa pine stands of the Ashland Ranger District and, possibly, other areas of eastern Montana, and recommendations for future fire history studies.

STUDY AREA

Although a brief reconnaissance was made during the fall of 2003 in the Sioux Ranger District, most of the field sampling and other research activities were focused on the Ashland Ranger District of the Custer National Forest (see Figure 1 for location). Therefore, what follows is a brief description of the Ashland RD project area largely derived from several sources including: the CNF website, www.fs.fed.us/r1/custer; the FEIS for the Threemile Stewardship Project (ARD, CNF 2002); and, Ecoregional Planning in the Northern Great Plains (The Nature Conservancy 1999).

Originally known as the Otter Forest Reserve, the present-day Ashland Ranger District is located in eastern Montana approximately 160 miles southeast of Billings, the administrative headquarters of the Custer National Forest. Extending north-south about 42 miles and 33 miles east-west, with a total land area of 502,152 acres, the Ashland RD is currently the largest contiguous block of forest covered public lands in eastern Montana. The USFS administers 87 percent (438,075 acres) of the lands within the district while 13 percent (64,077 acres) is in other, mostly private, ownership. The nearest settlement is Ashland, Montana, lying just a few miles west of the ranger district lands and the location of the Ashland Ranger Station.

Physiographically, the Ashland RD is positioned on a remnant plateau located between the Tongue and Powder River watersheds. Over time, the plateau has

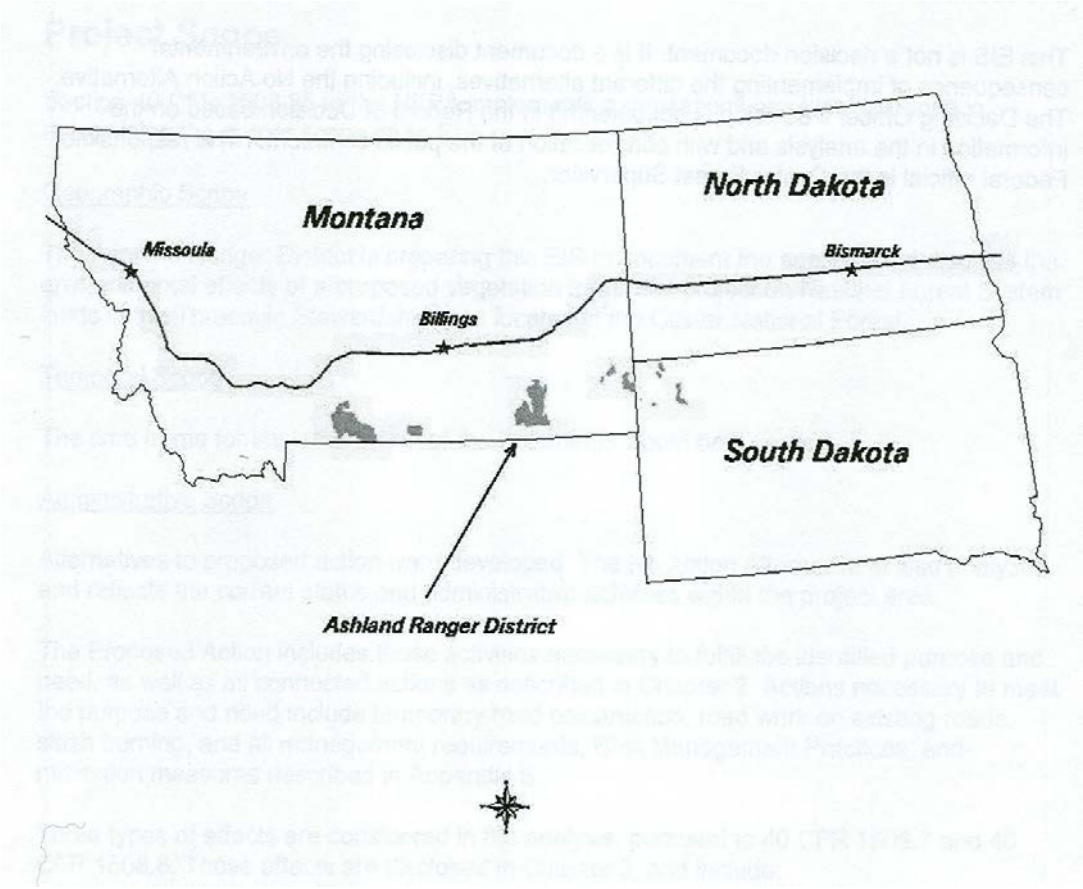

Figure 1. Location of the Ashland Ranger District, Custer National Forest (from ARD, CNF 2002).

experienced extensive erosion creating a variety of landforms including foothills, broad plains, ridge tops, deep ravines, steep cliffs, and river breaks bordering the Tongue River valley. With an elevation ranging from 3,200 to 4, 300 feet, this plateau receives precipitation varying between 11 and 15 inches which is sometimes a bit higher than surrounding low-lying grasslands and sagebrush country (Losensky et al. 1995). From a distance, the elevated plateau of the Ashland RD has the appearance of a dark ponderosa pine covered "island" surrounded by a lighter "sea" of grasslands.

The Ashland Ranger District is situated within a larger regional landscape sometimes called the Wolf Mountains. According to the authors of The Nature Conservancy ecoregional plan for this landscape:

> The Wolf Mountains are blanketed by low elevation coniferous forest/woodland (ponderosa pine forests and woodlands) with openings supporting Idaho fescue, bluebunch, and little bluestem grasslands. Ravines of the mountains and foothills support deciduous and mixed deciduous-coniferous wooded draws, while small streams give rise to shrub riparian natural communities. Surrounding plains are frequently covered by western wheatgrass grasslands. (TNC 1999, p. 180)

The Wolf Mountains encompass most of the Ashland RD, as well as much of the neighboring Northern Cheyenne Reservation and a small part of the Crow Reservation to the west.

The diverse landscape of the Ashland RD provides habitat for a variety of game animals such as elk, mule deer, pronghorn, grouse, and turkeys as well as numerous non-game species. A number of animal and a few plant species classified as USFS Northern Region (RI) Sensitive Species are found or may be present in the ARD. These include: "northern goshawk, Townsend's big-eared bat, spotted bat, sage grouse, black-tailed prairie dog, burrowing owl, black-backed woodpecker, loggerhead shrike, northern leopard frog, Barr's milkvetch, and pregnant sedge" (ARD, CNF 2002, pp. 3-52-53). Because of this diversity, The Nature Conservancy has given the Wolf Mountains, including the Ashland RD, a Biodiversity Rating of High within the Northern Great Plains Steppe Ecoregion (199).

As noted above, ponderosa pine forests and savannas---defined as scattered trees with less than 25 percent canopy coverage in grasslands (Pfister et al. 1977)---dominate the Ashland RD landscape (USDA-FS 1994). This low elevation variety of ponderosa pine (*P. Ponderosa* var. *scopulorum* Engelm.) is at the eastern edge of the species range

in western South Dakota, and eastern Montana, Wyoming, and Colorado (Morgan et al. 2002).

Ten ecosystem categories, based on vegetative characteristics and distribution, have been delineated and mapped for the ARD. The two ecosystems dominated by ponderosa pine are **Dry Slope Ponderosa Pine** and **Moist Slope Ponderosa Pine** (ARD, CNF 2002, p. 3-17). In the Dry Slope ecosystem (Figure 2a):

> The topography consists of gentle to steep, dry, sparely timbered southern slopes and ridges with some exposed shale and sandstone. Tree canopy cover is generally less than 25 percent. Vegetation is composed of a sparse overstory of ponderosa pine with a grassy understory. Typical plants are ponderosa pine, skunkbush sumac, and little bluestem.

In contrast, with the Moist Slope ecosystem (Figure 2b):

> The topography consists of timbered hilly uplands and moist northerly slopes. The slope gradient is generally from 15 to 50 percent. Typical plants in this ecosystem are ponderosa pine, juniper, Idaho fescue, chokecherry and snowberry. The density of the pine overstory varies, but is greater than 25 percent and in some cases, approaches 100 percent crown closure.

The photos in Figures 1a and 1b visually illustrate the descriptive characteristics of these ecosystems and show that they are very similar to the dominant Fire Groups of the Ashland Ranger District (Fischer and Clayton 1983).

Historically forest succession in most forest habitat types found in the USFS Northern Region (R1), including in eastern Montana, has been significantly influenced by wildfire (Pfister et al. 1977). To help understand and manage fire, the forest habitat types of Montana have been classified into 12 Fire Groups. The dominant Fire Groups of the Ashland RD are Fire Group Two (warm, dry ponderosa pine habitat types) consisting "…of open ponderosa pine stands with a predominantly grass

Figure 2a. Looking NE at Dry Slope Ponderosa Pine Ecosystem on south facing sandstone cliffs, “hoodoos”, and talus slopes located about a mile west from Ft. Howes on the Cow Creek Road(4095).

Figure 2b. Looking SW at Moist Slope Ponderosa Pine Ecosystem on north facing slope located along Whitetail Creek about 2 miles northeast from Whitetail Campground on FS Road 4427.

undergrowth and dense mixed-aged stands of ponderosa pine" and Fire Group Three (Warm, moist ponderosa pine habitat types) often existing as stands of "…stagnant, overgrown thickets of ponderosa pine saplings" (Fischer and Clayton 1983, p. 3). Although it is well known that ponderosa pine in eastern Montana is a fire dependent species---especially in relation to stand development, composition, and structure---there is very little authoritative information about the role of fire and range of natural variation in ponderosa pine fire regimes during pre-EuroAmerican settlement times in the Ashland Ranger District.

REPEAT PHOTOGRAPHY ANALYSIS

Historical ecology is the process of using historical information to develop an understanding of the past structure and function of an ecosystem---the range of historic natural variability (Bismanis et al. 2003; Egan and Howell 2001; Swetnam et al. 1999). Among the many methods of historical ecology are dendroecology, which will be discussed and utilized at length later, and repeat photography. Repeat photography involves a comparison between two photographs taken at the same place at different times. By comparing the two photos, changes become dramatically evident and this offers a unique resource for observing changes in vegetation and the landscape over time (Trimble and Cooke 1991). Accordingly, "repeat photography is a simple and inexpensive tool for reconstructing past environmental changes and monitoring future ones; it is particularly well suited for the relatively open landscapes of the western U.S."(retrieved 12/30/05 from www.cpluhna.nau.edu/Tools/repeatphotog.html).

There have been a number of published studies using repeat photography that compared photos showing historic vegetation composition and structure with those of today, including the work by Phillips (1963) on the northern Great Plains. More recently, "during 1994, the Northern Region and Custer National Forest of the U.S. Forest Service initiated a study to document historic and present landscape vegetation composition and patterns throughout southeastern Montana and western North and South Dakota" (Losensky et al. 1995, pg. 3). This research resulted in an unpublished report entitled A Description of Historic Vegetation Patterns and Trends on the Northern Plains Using Repeat Photography. One of the co-authors---Jeff DiBenedetto, Forest Ecologist, Supervisor's Office, Custer National Forest---kindly made a copy of the manuscript available for my use in this project. What follows is a summary of the observations made by J. Losensky, R. Clark, and J. DiBenedetto from repeat photography done in the Ashland Ranger District. For this study, from their report, I have selected four paired sets of historic and recent (1994) photographs to illustrate vegetation composition, structure and changes in northern, south-central and southwestern localities of the Ashland RD.

The first pair of photos (Figures 3a and 3b) are looking northwest from Little Pumpkin Creek towards the divide between Beaver Creek and the east fork of Otter Creek. In the 1905 photo (Figure 3a), grass dominated the south facing slopes and the ravine bottoms, medium and pole sized ponderosa pine grew on the north facing slopes, and scattered ponderosa pine grew on the ridge tops and upper hill slopes. The 1994 photo (Figure 3b) clearly shows grass still covers parts of south facing slopes and flatter areas of the draw, but it is much less dominant. Sapling, pole sized and medium sized

Figure 3b. Looking NW towards Beaver-Creek – Otter Creek Divide – 1905.

Figure 3b. Looking NW towards Beaver-Creek – Otter Creek Divide – 1994.

ponderosa pine trees have increased significantly on north facing slopes that were once more open.

The next pair of photographs (Figures 4a and 4b) were taken from the site of the Fort Howes Ranger Station, south-central ARD, and look east across the main Otter Creek valley towards west facing hill slopes and ridgelines. In the photograph taken in 1918 (Figure 4a), scattered Rocky Mountain juniper and ponderosa pine trees grow on the hill slopes and ridges while some bare ground and sparse grass cover is seen in the foreground. The 1994 photo (Figure 4b) shows a thick cover of western wheatgrass and neeedleandthread grasses in the valley bottom of the foreground, whereas ponderosa pine and Rocky Mountain juniper with a bunchgrass understory still dominate the background. The apparent loss of trees on the butte in the far background is attributed to the 1960s Chelsea Fire.

Figure 4a. Looking E from the "administrative structures" of the Fort Howes Ranger Station – 1918.

Figure 4b. Looking E from location of historic “administrative structures” at Fort Howes Ranger Station – 1994.

The next two pairs of contrasting photographs (Figures 5 and 6) portray conditions and changes in the landscape of Poker Jim Butte in the southwestern corner of the Ashland Ranger District. The photos in Figures 5a and 5b are looking southwest with the east side of Poker Jim Butte in the background and ponderosa pine savanna in the foreground. Figure 5a is a photo taken in 1925 and shows ponderosa pine scattered across the top of Poker Jim Butte and in the ravines leading away from the butte. By the time the second photo (Figure 5b) was taken in 1994, ponderosa pine is much thicker on the hill slopes and in the draws. The north facing slope of Poker Jim Butte, that was covered with grasses in the 1925 photo is covered with ponderosa pine in 1994 photograph. Nevertheless, despite the increasing density and spread of ponderosa pine by 1994, the landscape is still as savanna like in appearance as it was in 1925.

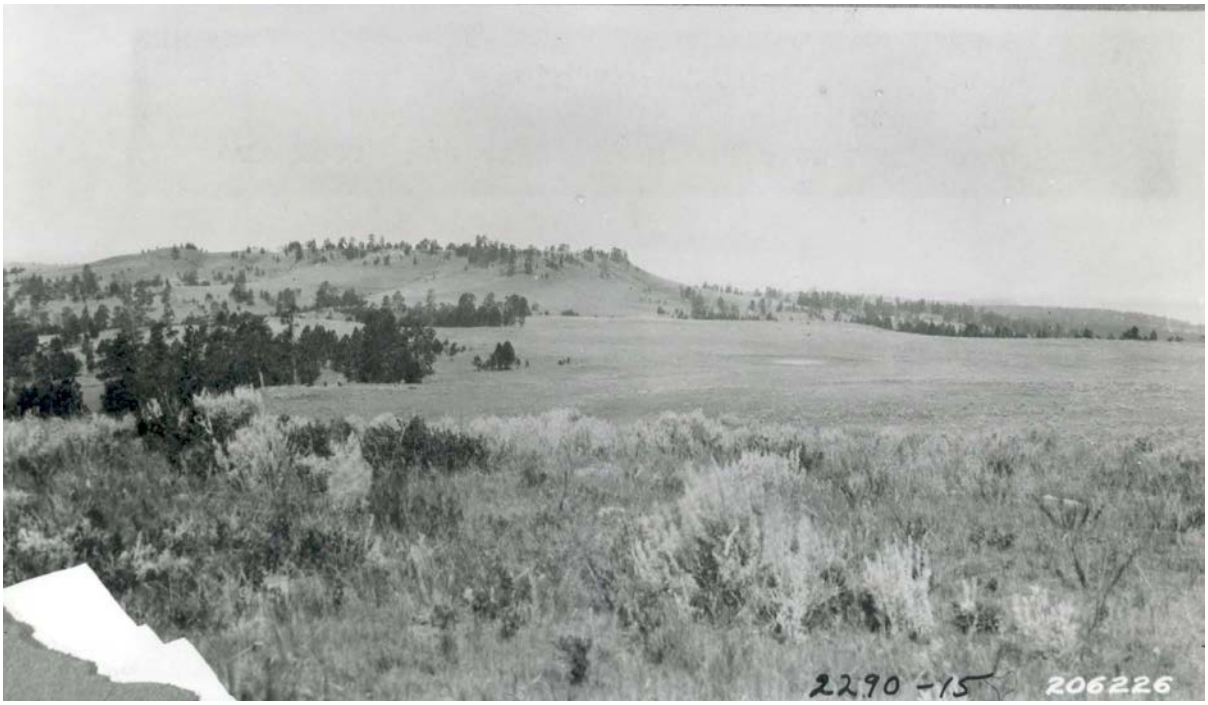

Figure 5a- Looking SW at east side of Poker Jim Butte – 1925.

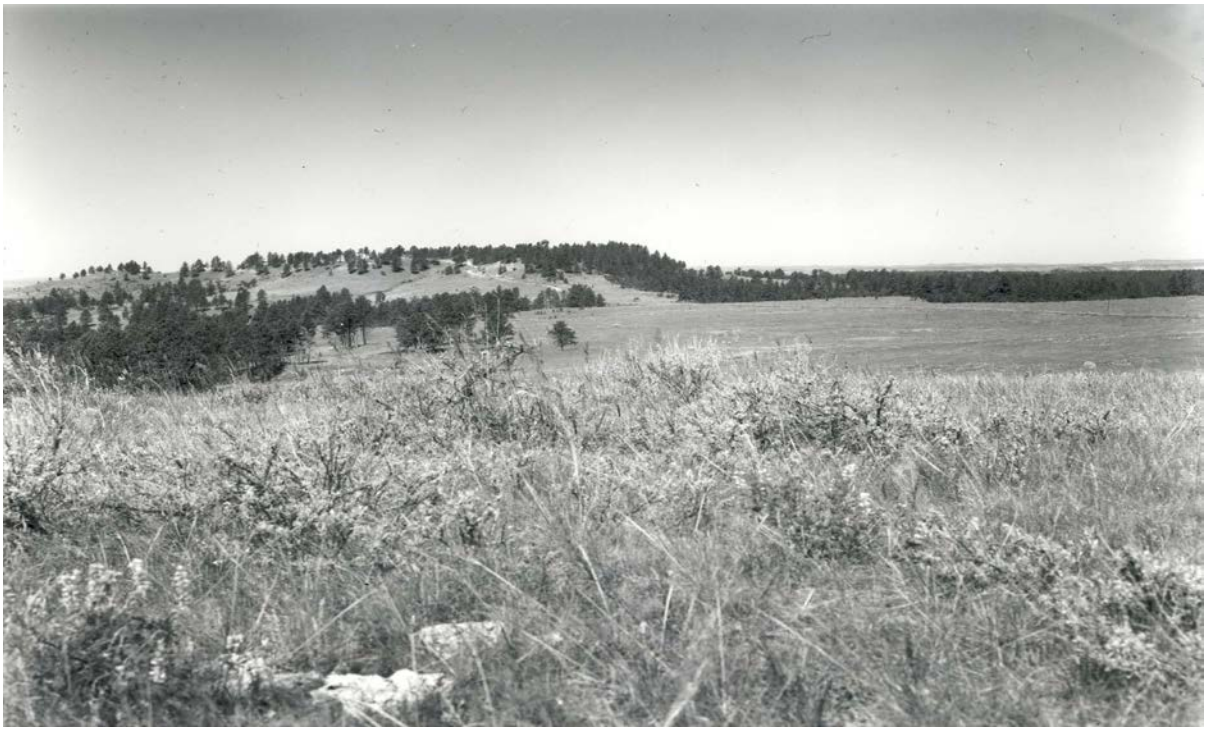

Figure 5b. Looking SW at east side of Poker Jim Butte – 1994.

Figures 6a and 6b are photos taken in 1915 and 1994 and are part of a series of panorama photographs taken from the southwest corner of Poker Jim Butte. In the background of the first photo (Figure 6a), ponderosa pine trees were mostly scattered on the hill slopes and in the surrounding ravines, while in the foreground pine trees appear to have been medium sized with a few snags present. The recent photo in Figure 6b shows that ponderosa pine cover has become more extensive as pines have spread out of the draws and encroached into the grasslands. Again, as in Figure 5, the ponderosa pine savanna that existed in the early 1900s continues into the late 20th century, albeit with the presence of more trees, most likely due to the suppression of fire.

Figure 6a. Looking NW from SW corner of Poker Jim Butte – 1915.

Figure 6b. Looking NW from SW corner of Poker Jim Butte – 1994.

The paired historic and recent photographs speak for themselves to a certain extent, but some generalizations can be made about environmental change, especially change in vegetation patterns, from the comparisons. Again, I have drawn from the discussions and conclusions made in the unpublished report by Losensky et al. (1995) and embellished them with my own field-based observations.

First, generalizing about the northern Great Plains as a whole, there appear to have been greater changes in forest and shrub communities than in grasslands and riparian vegetation types. In regard to forest vegetation types, especially ponderosa pine:

> There are more coniferous trees and shrubs on the [northern Great Plains] landscape today than one hundred years ago. Trees today are taller and canopies have expanded so that many of the previously open forested stands have closed. Many of the forested stands have expanded down and across slopes. (Losensky et al. 1995, no page number).

The overall landscape of the northern Great Plains remains dominated by grassland communities, but the composition and structure of these communities have changed in some areas. For example, Idaho fescue seems to have been added in more recent years to the historically present wheatgrass-needleandthread-green needlegrass plant associations in the grasslands of the Ashland Ranger District (USDA-FS 1994).

In highland areas of the northern Great Plains, like the ARD, where ponderosa pine occurred historically, there have been significant changes. In particular, according to Losensky et al. (1995):

> The greatest amount of change in vegetation pattern and structure occurred within coniferous stands associated with ridges, buttes and steep slopes in eastern Montana [including ARD]. In the original photographs, coniferous trees, principally ponderosa pine, are observed on the rockier sites of ridges, hillslopes and draws. This pattern is similar to that depicted in the Phillips and Shantz (1963) repeat photography series and is consistent to that reported by the Hayden expeditions (1869 and 1872)….They described these stands as open and stunted, implying the historic structure and pattern have been similar to that depicted in the early photos. (no page number)

It is assumed that this condition was probably due to the general absence of fine and ladder fuels (grasses and shrubs) growing on these rocky landforms with shallow, dry soils. With no fuels (exposed rock) or light and scattered fuels growing on impoverished soils, fires would have presumably burned less intensely and extensively in the past, allowing trees to escape fire effects and live to the old growth stage (cf. Morgan et al. 2002).

Although hill slopes and ravines, with deeper soils and more moisture, have the potential to support coniferous forests, they are not very dense or even present in the old photographs. In the recent photographs, ponderosa pines have spread from the hill tops and from draws onto the moister sites of north facing hill slopes, terraces, depressions,

and along the edges of grassy parks. These changes in the vegetation patterns are probably directly related to changes in the role of fire in the northern Great Plains, and the Ashland Ranger District in particular:

> The higher available moisture associated with these sites supports tree establishment and growth and also supports more grass and shrub growth creating greater amounts of fine and ladder fuels. Historically, the increased fuels would have supported more intense fires on these sites, removing trees before they became established or removed the stand completely, depending on the fire frequency. Hayden (1872) described this pattern and process, by reporting 'grass dominates wherever fire has swept up the hillsides destroying the pine trees'. This vegetation pattern and process is repeated today [and] can be observed in recently burned areas in eastern Montana. Remnant stands of trees occupy ridge tops and rock outcrops and grass and shrubs dominate hillsides with deeper soils, replacing the pine trees that had or were becoming established on these sites. (Losensky et al. 1995, no page number)

Clearly, fire, or the lack of it, has played a significant role in changing the vegetation composition and structure on the landscape of the northern Great Plains and the Ashland RD. Understanding the history of past fire regimes may help better interpret when, how, and why these landscape changes occurred.

FIRE HISTORY BACKGROUND

Before widespread settlement of the West by EuroAmericans, in the latter half of the 19th century, "fire was a keystone ecological process that shaped the composition and structure of many plant communities…" (Brown and Sieg 1996, p. 97). Since the late 19th century, natural fire has been excluded or reduced in many ecosystems by EuroAmerican land uses such as mining, logging, livestock grazing, and fire suppression (Savage and Swetnam 1990) and changes in climatic patterns (Swetnam and Betancourt 1999). In the last several decades, the U.S. Forest Service and other land management agencies have realized the importance of understanding natural fire regimes for

developing and implementing fire management programs such as prescribed burning. Understanding and restoring fire is central to newly emerging paradigms for ecological restoration of forests (Agee 2002; Allen et al. 2002) and the ecosystem management approach that has been adopted by federal agencies, including the USFS (Kessler et al. 1992; Robertson 1992).

Despite the obvious value of understanding the fire ecology and history of the low elevation ponderosa pine forests of eastern Montana, very little scientific research has been done in these forests. Because there is little fire history information for the ponderosa pine and other vegetation types of the Ashland Ranger District, existing published literature was reviewed that examined fire history from the nearest comparable areas in western South Dakota and northern Wyoming. Although this literature search is probably not exhaustive, the more relevant, recent and available documents are briefly summarized.

One recent study also notes that forest managers and scientists have only recently begun to focus on ponderosa pine in the eastern part of its range, particularly old-growth, and its ecological characteristics, especially fire history (Morgan et al. 2002). In an effort to remedy this situation, these authors report that their "…study examined five randomly selected old-growth ponderosa pine stands on state-owned land in central Montana [the Bull Mountains located north of Billings] for a variety of site-, stand-, and tree-level attributes" and observed that "areas of old-growth ponderosa pine typically occur along drainage features as a component of uneven-aged forests [presumably] maintained by low-intensity fires" (p. 11). This is evidenced by the fact that across these five ponderosa pine stands, between 14 percent and 43 percent of the old-growth trees exhibited external

fire scars, some with multiple scars. Although none of the fire scars were dated dendrochronologically, it is surmised that "the relative abundance of large trees with fire scars, coupled with the presence of multiple scarring, further supports the hypothesis that these were equilibrium sites frequented by low-intensity surface fires" (Morgan et al. 2002, p. 17). However, as the authors warn:

> The continued existence of old growth in the Bull Mountains, as throughout the inland West, is at risk from catastrophic fire and selective removal of old trees by high-grade logging. High densities of trees < 38.1 cm dbh at four of the five study sites pose a fundamental and immediate threat to the historic stand structure-disturbance regime. Should wildfire occur in these stands, the result probably would be a stand-replacement event signaling the transition from an equilibrium to nonequilibrium stand structure-disturbance regime. (p. 18)

Because of the catastrophic fire threat, it is recommended that management focus on forest restoration actions that reduce fuel loads, lessen densities of small diameter trees, and protect larger, older trees to sustain old-growth stands as a research resource that will provide additional, future insights into the dynamics of ponderosa pine forests east of the Continental Divide.

Comparable studies of ponderosa pine stand structures and endemic forest disturbances in the Black Hills region of South Dakota have revealed patterns and developments similar to what was observed in the Bull Mountains of Montana (Lundquist and Negron 2000; McAdams 1995; Parrish et al. 1996). For example, Parrish and co-authors (1996) observed that prior to pre-EuroAmerican settlement:

> Recurrent disturbances from fires, insects, and storms governed ponderosa pine structural attributes, densities, age class distributions, and population size. As a result, much of the Black Hills was probably a patchy forest mosaic composed of fire resistant older ponderosa pine over multiple age classes. Frequent low-intensity fires thinned out dense stands of seedlings and saplings. (pg. 17)

Even though the authors mention that historically there may have been significantly large patches of relatively dense old-growth (250-300 years old) ponderosa pine and large, contiguous areas of dense second growth pine in the northern Black Hills, they nonetheless conclude that "following a century of fire suppression and forest management, ponderosa pine is more dense and more [geographically] extensive" (p. 11). Similarly, McAdams (1995) quantified ponderosa pine tree basal areas and densities on 40 plots in the southern Black Hills and observed that, during the 1874-1995 period, ponderosa pine densities and basal areas increased five-fold in the 1-20 cm diameter-class trees, while larger diameter classes remained relatively stable (pp. ii-iii). The author concludes that the ponderosa pine forests of the Black Hills are much denser today, than prior to EuroAmerican settlement in the 1870s, due to the disruption of the natural fire regime, presumed to be characterized by frequent, low-intensity surface fires. Restoration of this type of fire regime, aided by extensive forest thinning, has been advocated in the recent management plans of the Black Hills National Forest.

Clearly, the prevailing view among forest scientists and managers in the western U.S., including the northern Great Plains, has been that pre-EuroAmerican ponderosa pine forests experienced frequent, low-intensity surface fires that created and maintained open, "park-like" forests dominated by large, old growth trees (Cooper 1960; Weaver 1974; Gruell et al. 1982; Covington and Moore 1994; Arno et al. 1995). Shinneman and Baker (1997), in a controversial article, called this view into question. They argue that, at least in the Black Hills of South Dakota and Wyoming, the historical range of natural variability in ponderosa pine ecosystems includes evidence of both frequent, low-intensity surface fires (the equilibrium model or regime) and large, unpredictable

catastrophic disturbances (the nonequilibrium model or regime). The result, according to these researchers, was equilibrium and nonequilibrium landscapes in the pre-EuroAmerican Black Hills. Equilibrium ponderosa pine landscapes resulted from frequent, low-intensity surface fires that maintained open, park-like forests of large, old trees especially in the southern Black Hills. Nonequilibrium landscapes resulted from large, stand-replacing fires and major mountain pine beetle kills that took place in extensive tracts of relatively dense, closed-canopy forests of old growth observed by early explorers (e.g., Custer, Dodge, Graves) in the northern and central Black Hills. These researchers conclude that, in addition to the prevalent equilibrium-based management prescriptions, we may need to manage for large, unmanaged landscapes where large-area, intense, stand-replacing fires can occur in naturally dense ponderosa pine forests. This nonequilibrium-based management approach "…complements a strictly equilibrium-based management emphasis, which stresses the protection of forest 'health' through intensive and widespread maintenance of a 'normal' range of conditions, but which overlooks the role of unmanaged and unpredictable events in maintaining healthy landscapes" (Shinneman and Baker 1997, p. 1287).

One of the first studies (Higgins 1984) that tried to quantify the role of fire in the ponderosa pine forests and pine savannas of eastern Montana and South Dakota, including the Sioux Ranger District of the Custer National Forest, focused on the historic record (between 1940 and 1981) of lightening caused fires. Higgins found that during the period studied:

> Lightning ignited fires in grasslands and pine-savanna lands during all months from April to September. Seventy-three percent of lightning ignitions…and 68% of the days with fires…occurred during July and August with lesser numbers in April, May, June, and September. Multiple ignitions (more than 1 fire in 1 area

> on a single calendar day) occurred in all months from June-September. Eighty-six percent of the days (n=44) with multiple ignitions occurred from July 1-August 31. (1984, p. 101)

It was also observed that the area burned by lightening caused fires ranged from 0.004-1158.3 hectares but that "eighty-eight percent of these fires burned an area of 3.64 ha or less" and that "only 2 fires burned more than 405 ha; both occurred in July" (Higgins 1984, p. 101). Finally, in the 42 year record during the 20th century, an area of 66, 015 hectares, in the ponderosa pine savannas of the Sioux RD, experienced 254 lightning set fires, most of which were suppressed, for a fire frequency of 6.05 per year (Higgins 1984, p. 102). Overall, this study indicated that lightning was and is an extremely important ignition source in the Sioux RD and another study (Clark 1993) has subsequently shown that it is even more significant in the Ashland Ranger District. Clark, summarizing Fires on the Custer National Forest: 1953-1992, showed that over the 40 year period, the Ashland Ranger district experienced percentage-wise the largest total acreage burned (29.61%), the greatest number of fires (61.46%), and the highest percentage of lightening caused fires in the CNF (70.43%) (1993, pp. 2, 12, and 16).

The first fire history study based on sampling physical evidence of fires (i.e., fire scars) in the prairie-forest mosaic of the northern Great Plains was done by Fisher et al. (1987) at Devils Tower National Monument in Wyoming. Using simple ring counting, not dendrochronologically accurate cross-dating, this study produced a 27 year mean fire return interval (MFI) prior to 1770, a 14 year MFI between 1770 and 1900, and a 42 year MFI after 1900 in ponderosa pine forest types. According to Fisher et al., "if we use 1900 as the date after which most permanent settlement occurred in the area, then the presettlement fire return period was 19 years" and "this is less than half the time between

fires since settlement" (p. 253). Most fire years, represented by scars, were found on only one or a few trees and were thought to be lightening caused spot fires localized and of short duration like most of those analyzed by Higgins (1984). Again, based on ring counting only, other fire yeas were classed as local (fires represented on scars on trees scattered over at least one third of the study area) and regional (fires represented by scars on trees occurring in every part of the monument) (Figure 7).

TABLE 1.—Dates of area-wide or regional fires as inferred from the occurrence of fire scars throughout the area in any one year

1632	1730	1791	1869
1660	1769	1806	1893
1676	1776	1820	1937
1694	1785	1845	

TABLE 2.—Dates of local fires as inferred from the occurrence of fire scars scattered over a portion of the area

1620	Tower area	1859	Tower area and east side
1695	West side	1864	Tower area
1714	Tower area	1875	Tower area and east side
1753	Tower area and west side	1886	Tower area and east side
1760	Tower area and west side	1890	Tower area and west side
1765	Tower area	1921	Tower area and east side
1836	Tower area and northeast		
1838	Tower area and west side		

Figure 7. Regional and local fire years in Devils Tower National Monument (from Fisher et al. 1987, p. 252).

Adopting what has become know as the equilibrium view of ponderosa pine fire history, Fisher et al. concluded that:

> …prior to fire prevention, the prairie-forest mosaic at Devils Tower seems to have been stable. The savanna was probably more open and the prairie area somewhat larger than prior to 1770 because the mosaic was in equilibrium with a 14-year fire return period rather than the 27-year return period prior to 1770. After 1900, the fire return period dramatically lengthened. This has resulted in the area of prairie diminishing and the savanna becoming more dense, even becoming forest in some areas. (Fisher et al. 1987, p. 256)

Analysis of soil opal-phytolith data from the Devils Tower NM corroborated the notion that a relatively stable ecotone existed between forest, savanna, and prairie in the pre-EuroAmerican settlement period followed by changing boundaries in the 20th century (p. 255).

Peter Brown, Director of Rocky Mountain Tree-Ring Research, has been the principal investigator conducting several fire history studies in the Black Hills region since the mid-1990s and has probably compiled the most extensive record of cross-dated fire chronologies in the northern Great Plains to date. In the first published research, fire event chronologies were reconstructed from fire-scarred ponderosa pine trees sampled at four sites in Jewel Cave National Monument located in the south-central Black Hills (Brown and Sieg 1996). Figure 8 illustrates the results of this research:

Table 1. a. Number of fire intervals, mean fire intervals (MFIs) (± SD) and ranges of fire intervals at four sites and all sites combined, using all detected fire dates. All sites combined are intervals between fire years recorded at any of the four sites. b. Number of fire intervals, MFIs (± SD) and ranges of fire intervals at four sites and all sites combined, using fire dates recorded when sample depth ≥ 2 trees and fire index (or percentage of trees recording a fire in that year) ≥ 25% (i.e. using dates in middle portions of Figure 2).

a. Site	Period	No. Fire Intervals	MFI (yrs.)	Range (yrs.)
JCS	1591 to 1900	13	23 ± 23	7 - 93
JCE	1591 to 1890	13	23 ± 22	1 - 77
JCN	1576 to 1890	16	20 ± 14	4 - 45
JCC	1388 to 1890	22	23 ± 18	1 - 63
ALL SITES	1388 to 1900	34	16 ± 14	1 - 45

b. Site	Period	No. Fire Intervals	MFI (yrs.)	Range (yrs.)
JCS	1684 to 1890	9	23 ± 23	7 - 79
JCE	1668 to 1890	11	20 ± 15	5 - 47
JCN	1663 to 1890	11	21 ± 13	6 - 45
JCC	1668 to 1890	7	32 ± 12	9 - 47
ALL SITES	1576 to 1890	16	20 ± 14	1 - 45

Figure 8. Fire intervals and mean fire intervals with varying sample depths for all sites at Jewel Cave National Monument, South Dakota (from Brown and Sieg 1996, p. 101).

The numerical detail of Figure 8 can be summarized thusly:

> For all sites combined, and using all fires detected, the mean fire interval (MFI), or number of years between fire years, was 16 years (± 14 SD) for the period 1388 to 1900. When a yearly minimum percentage of trees recording scars of ≥ 25% is imposed, the MFI was 20 years (± 14 SD). The length of the most recent fire-free period (104 years, from 1890 to 1994) exceeds the longest intervals in the pre-settlement era (before ca. 1874), and is likely the result of human-induced land use changes. (Brown and Sieg 1996, p.97)

Utilizing the position of fire scars within annual rings, the authors also reconstructed the seasonality of past fire events at Jewel Cave NM. As Figure 9 shows, it appears that most past fires "…occurred late in the growing season (i.e., scar recorded in the last third of the earlywood or in the latewood) or after growth had ceased for the year" (Brown and Sieg 1996, pg. 101).

Table 3. Number of fire scars by position within annual rings. Scar positions are: **Unknown earlywood**: position within the earlywood cannot be defined more precisely; **Early-earlywood**: within first 1/3 of earlywood band; **Middle-earlywood**: second 1/3 of earlywood; **Late-earlywood**: last 1/3 of earlywood; **Latewood**: within the latewood band; **Dormant**: between 2 rings; **Unknown**: due to narrowness of ring or quality of scar (Baisan and Swetnam 1990).

	Fire Scar Position						
	Earlywood						
Site	Unknown	Early	Middle	Late	Latewood	Dormant	Unknown
JCN	7	3	3	12	22	29	37
JCC	6	5	6	10	27	28	33
JCE	7	3	2	14	31	16	23
JCS	6	11	3	8	20	33	43
Total (%)	26 (5.8%)	22 (4.9%)	14 (3.1%)	44 (9.8%)	100 (22.3%)	106 (23.7%)	136 (30.4%)

Figure 9. Seasonality of past fires based on fire scar position in annual rings at Jewel Cave National Monument, South Dakota (from Brown and Sieg 1996, p. 102).

Although the seasonality of fire events in ponderosa pine forests seems to be similar to that found in the southwest or southern Rocky Mountains, the Jewel Cave area of the Black Hills experienced a lower fire frequency than observed in the southwest (Swetnam and Baisan 1996), which is consist with earlier research (Fisher et al. 1987).

Nevertheless "… even with these longer pre-settlement fire intervals, interior Black Hills ponderosa pine forests are not burning today nearly as often as they did in the past" (Brown and Sieg 1996, p. 104) which has important forest management implications---compare Brown et al. (2000) for similar observations, results and recommendations.

In a second paper, Brown and Sieg (1999) examine historical variability in fire at the northern Great Plains grasslands – Black Hills ponderosa pine ecotone (sometimes called ponderosa pine savanna) located in southern South Dakota and compare it with historic fire patterns reconstructed for interior ponderosa pine forests in the south-central Black Hills (Brown and Sieg 1996). As figure 10 details, cross-dated fire scarred ponderosa pine samples from three sites at Wind Cave National Park yielded mean fire intervals (MFIs) between 10-12 years, almost one-half the MFI of the interior forest sites at Jewel Cave NM in the south-central Black Hills.

TABLE II. Measures of fire frequency for three ponderosa pine savanna sites at Wind Cave National Park (GOB, PIG, and WCN) and four forest interior sites at Jewel Cave National Monument (JC site designations; Brown & Sieg, 1996). Fire intervals used in calculations are for all dates recorded on any tree at each site for the period of analysis

Site	Period of analysis	No. of intervals	MFI (± SD)[1]	Range of intervals[2]	WMPI[3]	5% to 95% prob. inter.[4]	Fire frequency (from Figure 4)[5]
WIND CAVE NATIONAL PARK							
WCN	1564 to 1896	27	12.3 ± 6.9	3 to 32	11.6	3.5 to 22.7	0.077
PIG	1528 to 1912	38	10.1 ± 5.8	2 to 23	9.3	2.3 to 20.3	0.100
GOB	1652 to 1910	21	12.3 ± 7.2	3 to 34	11.5	3.5 to 22.6	0.078
JEWEL CAVE NATIONAL MONUMENT							
JCN	1576 to 1890	16	19.6 ± 13.5	4 to 45	17.4	3.9 to 40.3	0.045
JCC	1388 to 1890	22	22.8 ± 17.6	1 to 63	18.8	2.6 to 57.0	0.042
JCE	1591 to 1890	13	23.0 ± 22.0	1 to 77	16.9	1.6 to 63.9	0.043
JCS	1591 to 1900	13	23.8 ± 23.1	7 to 93	20.1	4.6 to 46.3	0.043

[1] Mean and first standard deviation of all intervals in composite fire chronology in years.
[2] In years.
[3] Weibull median (50% exceedance) probability interval in years.
[4] Weibull 5% and 95% exceedance probability intervals in years.
[5] Slope of line of cumulative fire dates (number of fires year^{-1}).

Figure 10. Various measures of fire frequency in three ponderosa pine savanna sites at Wind Cave National Park, South Dakota (from Brown and Sieg 1999, p. 544).

The higher frequency of fires in the ponderosa pine savanna was "…most likely due to the [greater] spatial extent of fires on the mixed-grass prairie coupled with [a] warmer and drier climate regime" (Brown and Sieg 1999, p. 539). Regarding fire seasonality, the majority (61.7%) of fire scars at Wind Cave NP were recorded in the latewood or dormant portion of annual rings suggesting a late season fire pattern similar to other fire records (Higgins 1984; Brown and Sieg 1996). Finally, the authors conclude that intensive livestock grazing and contemporaneous loss of surface fire in late 19th century probably corresponds with shifts in the ecotone between grasslands and forests with increasing encroachment of woody plants into prairie areas.

To summarize this brief literature review, using simple ring counting, a mean fire return interval (MFI) of approximately 20 years was identified in ponderosa pine stands adjacent to the Devil's Tower National Monument in northeastern Wyoming. Using dendrochronological methods, a 20 year MFI was observed in the heavily forested Jewel Cave area of the central Black Hills in South Dakota, while in the ponderosa pine savanna of the Wind Cave area of the southern Black Hills, there was a 10-12 year MFI. All of these studies, including an early one focusing on lightning caused fires, show that the majority of fires in the ponderosa pine forests and pine savannas of the northern Great Plains tended to start and burn in the late or dormant growing season of July and August. Finally, at least one paper argues for the historic existence of large, stand-replacing fire disturbances (nonequilibrium conditions) in dense old-growth ponderosa pine, at least in the northern part of the Black Hills, as well as the more commonly recognized smaller, low-intensity fire disturbances (equilibrium) that occurred primarily in the central and southern areas. Overall, given this information, MFIs ranging between 10-20 years in the

ponderosa pine of the Ashland Ranger District might be anticipated, with the chance of a north-south gradient in MFIs, if there is a climatic gradient, and even the possibility of evidence for pre-EuroAmerican settlement, as well as recent, stand replacing fires.

FIRE HISTORY PILOT PROJECT

In addition to studying available repeat photography and doing an extensive literature review, considerable effort for this pilot project went into determining the feasibility of finding physical evidence that might allow reconstruction of a fire history in the Ashland Ranger District. After an initial reconnaissance trip in the early fall of 2003, that determined the existence of old-growth ponderosa pine and fire scarred trees, several subsequent, week-long, field trips were made to the Ashland RD in late fall of 2003 and, once more, in the summer of 2005. Field work consisted of collecting increment borer samples from living trees and "wedges" from fire scarred living trees and tree remnants (i.e., stumps and deadfall), as well as making general observations about forest ecology and conditions. In between and after field sampling trips, considerable time was spent preparing samples for analysis and actually analyzing them for fire history reconstruction. In this section, the core and fire scar collecting and processing activities, as well as the results of the ponderosa pine fire history analysis, will be described.

In ponderosa pine, and some other thick-barked tree species, "fire scars result when surface fire kills cambial tissue along a portion of a tree's growing circumference, forming a lesion visible in the tree rings" (Brown and Sieg 1996, p. 98). Due to repeated fire events occurring during the life of a "recorder" tree, sequences of fire scars are often recorded. Of course, not all fires that burned around a tree's base were recorded as a scar

and subsequent weathering and/or burning may have removed evidence of earlier fire scars (Brown and Swetnam 1994). Furthermore, the number of scars is often directly related to the age of a tree, so it is important to sample from trees with a large number of scars, if possible. To extend the time depth beyond the age of living trees, it is also important to sample from remnants (e.g., stumps and snags) representing older trees in the stand.

Cores and fire scar samples were collected from several localities in the Ashland RD (see Figure 11). At each fire scarred tree or remnant, a full or partial cross-section sample is removed by chain saw from the fire scar face (Arno and Sneck 1977). Approximately 30 individual scar samples were collected, although many of them have not proven datable for a variety of reasons (e.g., scars burned off or too rotten). Most of these have been recovered from stumps remaining from 19th and/or 20th century logging activities. A few scar samples were also extracted from snags, downed tree remnants, and, occasionally, a live old growth ponderosa pine tree. The majority of the samples were collected from the North Fork Poker Jim (NFPJ) locality in 2003 and 2005, but other small collections have been made from Beaver Creek (BECR), North Fork Whitetail Creek (NFWC), East Fork Otter Creek (EFOC), the Rock Quarry site (ROQU) in 2003 (see Figure 11). Cross-section samples were taken to the laboratory where they were first thin sectioned by band saw and hand planer. Next, the samples were belt sanded to a 400 grit (very fine) surface to maximize annual ring visibility during analysis. Sometimes, field samples were discarded at this point because preliminary lab analysis showed fire scars were not sufficiently preserved to accurately record fires. Nevertheless, a small subset (17 trees/remnants and 36 fire scars) was used in this initial analysis.

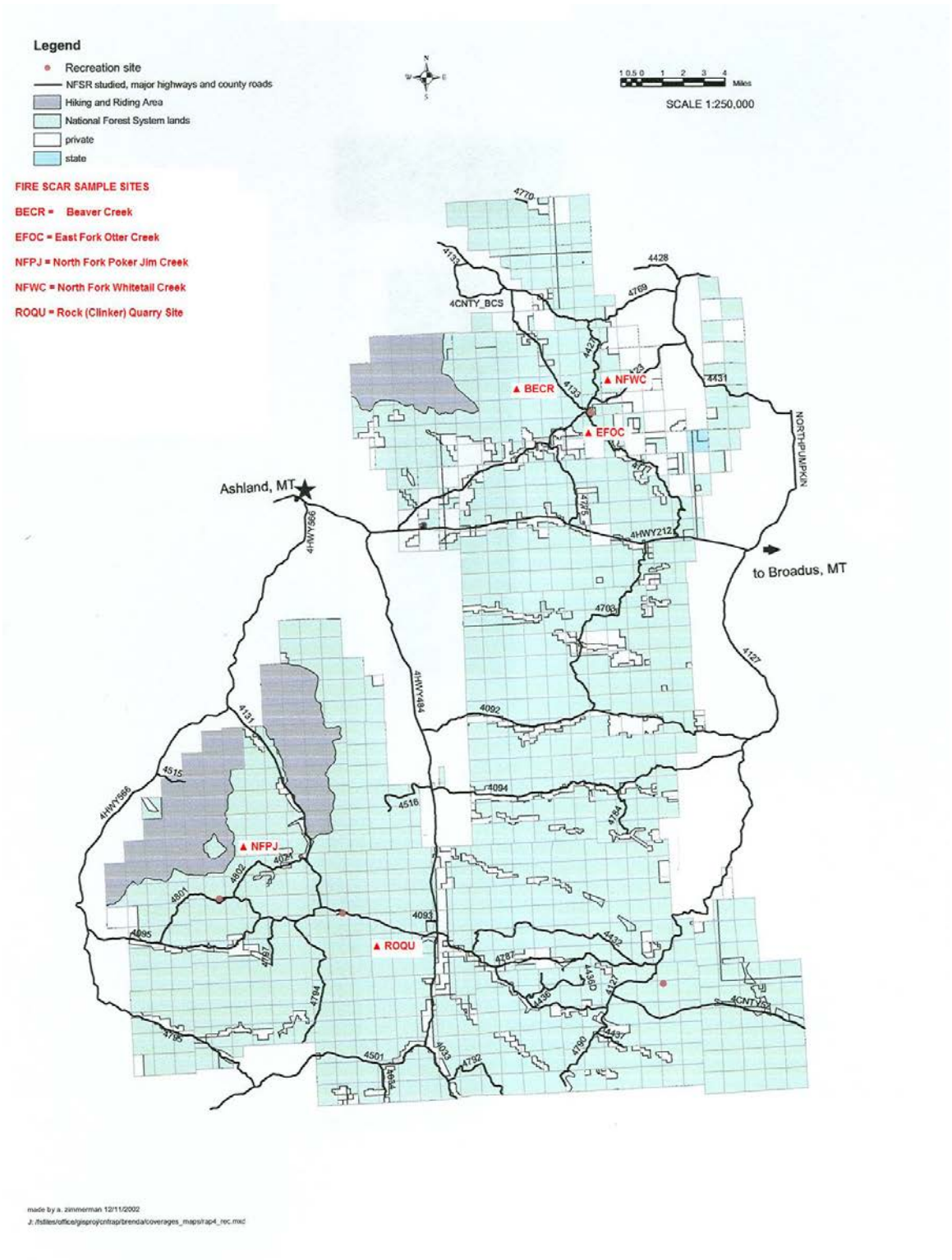

Figure 11. Map of Ashland Ranger District showing location of core and fire scar sample sites (ARD, CNF 2002).

All tree-ring series from the samples discussed below were cross-dated using standard dendrochronological techniques (Stokes and Smiley 1968; Swetnam et al. 1985). An initial master chronology was developed for cross-dating purposes using core samples from late-successional trees and scar samples from living old growth trees. After the sampled tree ring series were cross-dated, dates were assigned to the fire scars in each fire scar sample. Cross-dating provides absolute dates for fire events recorded as scars and allows utilization of remnant (e.g., stump) material to reconstruct fire history. Position of fire scars within annual rings were recorded where possible and utilized to infer seasonality of fires (Dietrich and Swetnam 1984; Baisan and Swetnam 1990). All cross-dated fire history data was analyzed utilizing FHX2 software, which was developed by Dr. Henri Grissino-Mayer at the Laboratory of Tree-Ring Research "…for the explicit purpose of analyzing fire history of forest ecosystems as revealed by fire scars and other fire-related injuries that are often found in the annual rings of trees" (Grissino-Mayer 1995: 7).

Approximately 100 cores and 30 fire scars were collected from trees or remnants from five sites (BECR, NFWC, EFOC, ROQU, and NFPJ)) in the northern and southern sections of the Ashland RD (Figure 11). Of these, 17 fire scar samples were successfully cross-dated by a research assistant and the principle investigator. While several of the sample site sizes are quite small, making it difficult to reconstruct past fire patterns with certainty (Baker and Ehle 2001), they were within the low end of the size range utilized for fire history studies from other sites in the southwest and Rocky Mountains (cf. Baisan and Swetnam 1990, Bragg et al. 1998). To compensate somewhat for small site sample sizes, the northern sample sites (BECR, EFOC, and NFWC) were combined into Ashland

District – North (ADNO) and the ROQU and NFPJ sites were combined into Ashland District – South (ADSO). In addition, in the analysis, both of these aggregated samples were combined into Ashland District – North and South (ADAL) to create a fire chronology for the entire Ashland RD. In subsequent re-analysis samples with fire scars that only dated from the 20th century were extracted from ADAL to form a separate fire chronology labeled Ashland District -Twentieth Century (ADTW).

Examination of fire chronologies and summary statistical data derived from FHX2 analysis of the aggregated sites (ADNO and ADSO) (Figures 12-13), as well as a combined fire chronology for all sites (ADAL)(Figure 14), reveals a tree ring fire record extending form 1729 to 2005 (277 years) with 36 fire scars for the entire sample set. In addition, there is some agreement (overlap) in fire event dates both within and between sites.

The horizontal lines, on the master fire chronology graphs of Figures 12-15 below, represent time spans of individual tree/remnant samples and vertical lines symbolize dated fire scars. Fire scar data shown on the composite (X) axis at the bottom of the master chronologies (Figures 12-15) combines information from individual samples at a site or sites. The individual information was filtered in order to highlight historic fires that burned more than one tree over larger areas, both within and between sites in the study area (Grissino-Mayer 1995). The filters utilized in this particular study were: 1) sample depth = 2; and, minimum sample = 1. This set of filters allowed comparison of small sample, small sites (e.g., EFOC and ROQU) with larger sites and samples (e.g., NFPJ). The resulting fire chronology graphs (Figures 12-15) follow:

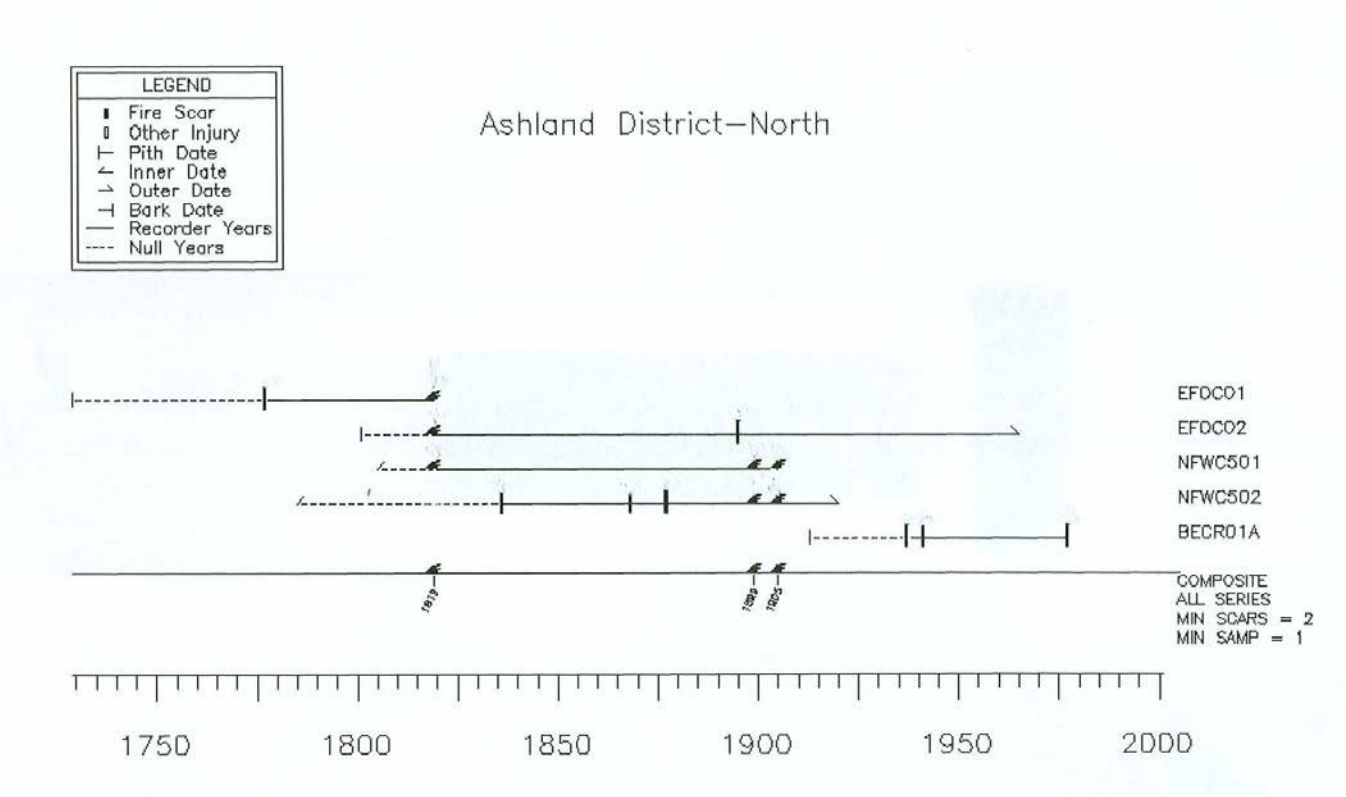

Figure 12. Fire chronology for the northern Ashland Ranger District sites (ADNO).

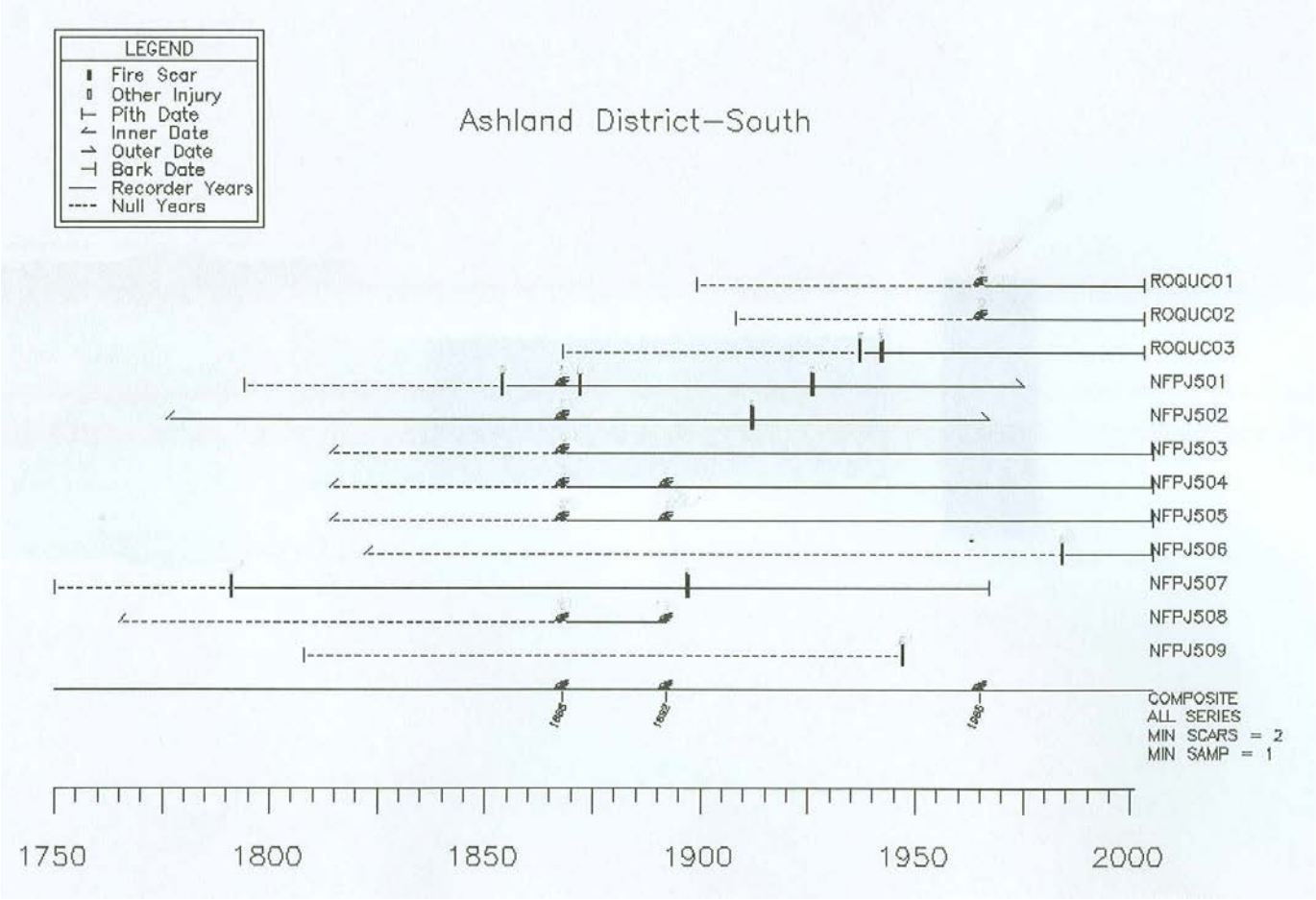

Figure 13. Fire chronology for the southern Ashland Ranger District sites (ADSO).

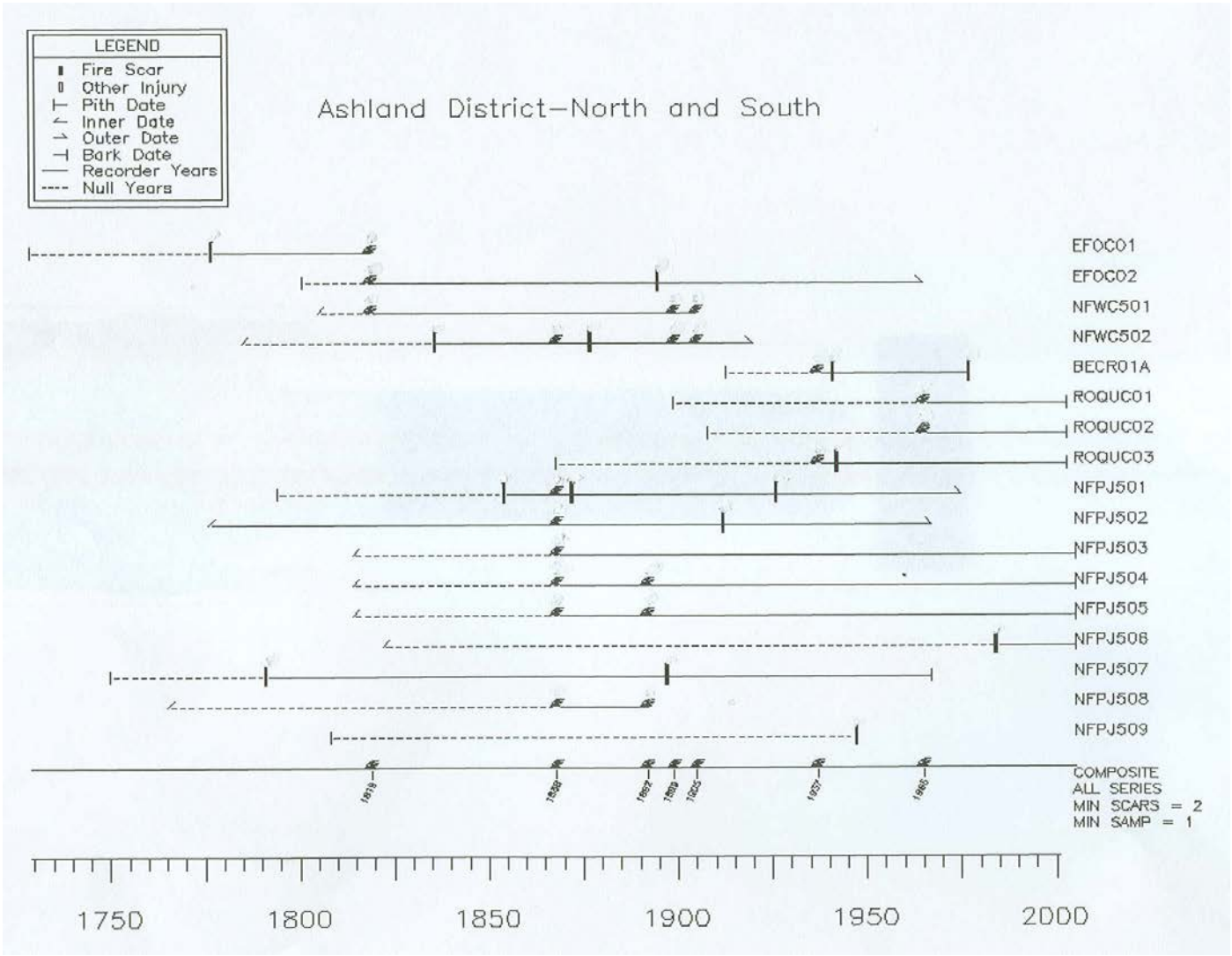

Figure 14. Fire chronology for all the Ashland Ranger District sites (ADAL).

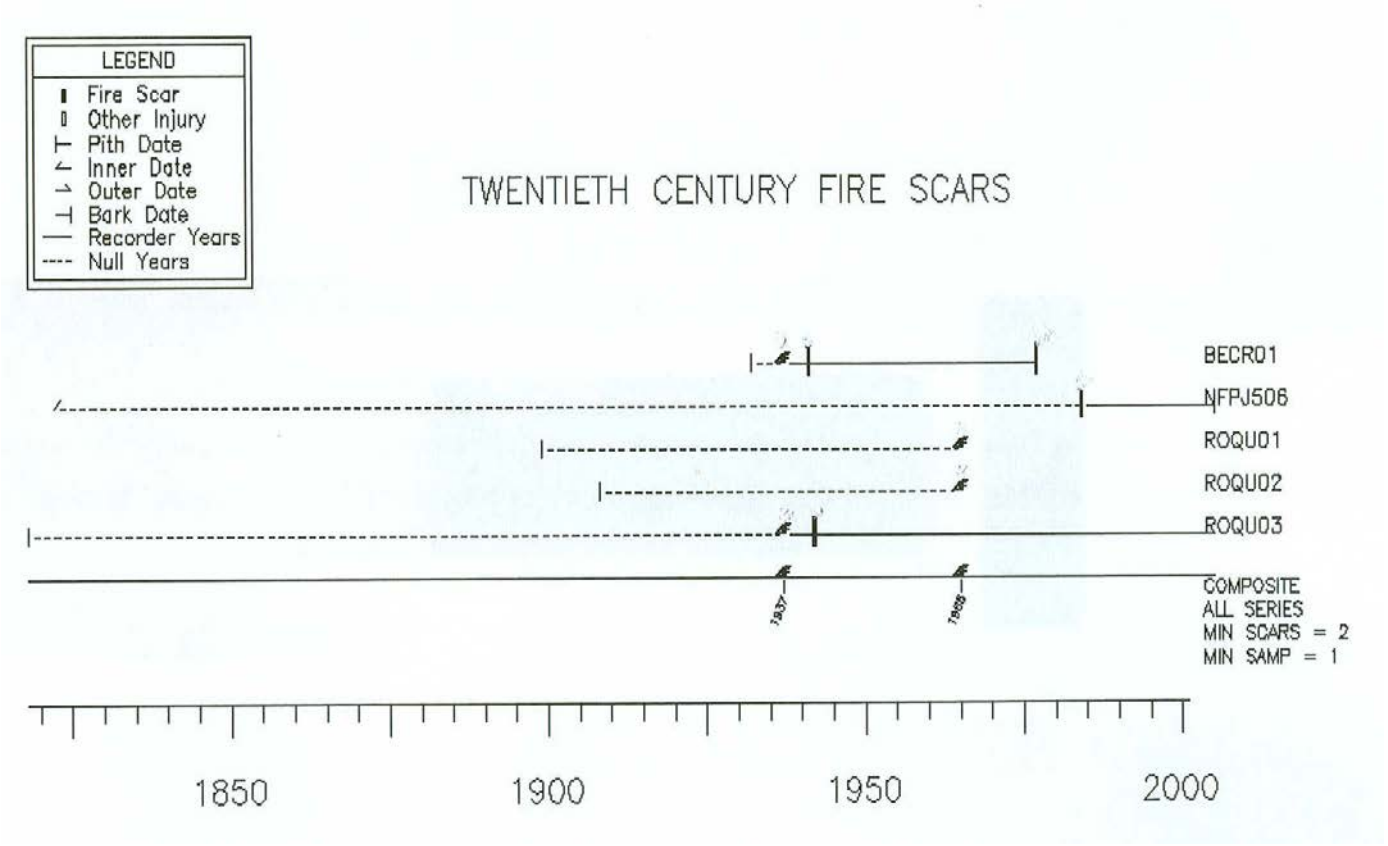

Figure 15. Fire chronology for 20th century fire scar sites (ADTW).

Table 1 is of interest because it displays the composite fire years, shown at the bottom of figures 12-15, when fires burned more than one tree, sometimes at more than one site, and, occasionally, in both the northern and southern parts of the ARD.

Table 1. Distribution of Composite Fire Years in Ashland Ranger District

Composite Fire Years			
Year	North (ADNO)	South (ADSO)	Total
1819	3		3
1868	1	6	7
1892	3		3
1899	2		2
1905	2		2
1937	1	1	2
1965		2	2

This table illustrates that in certain years some fires occurred in several areas with the ARD. Eighteen sixty-eight (1868) and nineteen thirty-seven (1937) are the only years that record fires in both the northern and southern sections of the Ashland RD, so most historic fires were probably quite localized and small in extent. Of course, it is really impossible to know the true spatial extent of fires in any years beyond the boundaries of the sampled trees and remnants, especially with small nonrandom samples. It is also most likely that scars recorded on scattered trees at several widespread sites are from different fire ignitions occurring in the same year and do not actually represent a fire that burned simultaneously over a large geographic area. This seems especially likely in the case of the 1937 fire when there would have been at least minimal fire suppression capabilities in the Ashland RD.

Table 2 summarizes several fire interval statistics for the Ashland Ranger District fire-scar chronologies (Figures 12-15).

Table 2. Summary of fire interval statistics for Ashland Ranger District Sites

Fire Intervals (FI) in Years						
Site	Period	#FI	MFI	MDFI	WMPI	RangeFI
ADNO	1729-2003	10(7)	20(18)	17.5(17)	17(15.5)	4-42
ADSO	1750-2005	12(8)	16(19.5)	14(19.5)	13(16)	4-63
ADAL	1729-2005	21(15)	10(11)	7(14)	8.5(10)	1-28
ADTW	1900-2003	5	9.5	7	7	1-23

( ) = Fire interval statistics calculated without 20th century fire scars.

Fire return intervals range from 4 to 42 years at the aggregated northern sites (ADNO) and 4 to 63 years at the combined southern sites (ADSO), but exhibit a narrower range, from 1 to 28 years, when all sites sampled in the Ashland RD are combined. All three measures of central tendency---Mean (MFI), Median (MDFI), and Weibull Median Probability Interval (WMPI)---usually fall within one or two years of each other. Mean Fire Interval (MFI) varies from 16 (ADSO) to 20 (ADNO) and is 10 years for all sites combined. The MDFI tends to be closer to the WMPI than the MFI and usually smaller. Because the WMPI is "…based on a model that conforms to the typical non-normal shape of most fire interval distributions…" (Swetnam and Baisan 1996, p. 20), it is considered statistically more robust and, therefore, a more accurate measure of central tendency in fire intervals. The WMPI ranges from 13 (ADSO) to 17 (ADNO) and is 8.5 years for all sites (ADAL). It is certainly possible that the higher MFIs and WMPIs at the

northern sites (ADNO), compared to the southern sites (ADSO), reflect the differences between what may have been and still may be a denser, interior-like forest in the north versus a less dense, more ponderosa pine savanna-like situation in the south. If this distinction is valid, this situation would be similar to the comparative differences between interior and savanna ponderosa pine forests that Brown and Sieg (1999) found in the Black Hills. However, since the fire interval differences are not as great in the Ashland RD, they may simply reflect small sample sizes. More extensive and larger samples will be required to resolve this question.

Other researchers have noted either a considerable lengthening of fire intervals (Fisher et al. 1987) or the cessation of fires altogether (Brown and Sieg 1996) at the end of the 19th century in the northern Great Plains. This significant alteration in fire patterns is thought to reflect profound changes in land use by EuroAmericans, including early widespread, intensive livestock grazing and later direct fire suppression (Brown and Sieg 1999). Although the majority (28 or 78%) of recorded fire scars, mostly sampled from old growth trees and tree remnants, examined from the Ashland RD reflect fire events from the 18th and 19th centuries, a small sample of fire scars (8 or 22%) were dated to years in the 20th century. In addition, numerous, mostly small diameter, and apparently younger (blackjack), scarred trees were observed with single, and sometimes multiple fire scars, in both the northern and southern parts of ARD.

With the possibility that inclusion of these twentieth century fires in the total sample might be biasing the fire interval statistics, they were removed from the other sample and then all analyses were rerun in FHX2. Interestingly, removal of the 20th century fire scars eliminates any noticeable differences in fire frequency between the

northern and southern sections of the Ashland RD. This may confirm that sampling errors created that sampling difference and that during the pre-EuroAmerican settlement period fire frequency was similar throughout the ARD. Also, surprisingly, the average fire intervals from the 20th century are noticeably shorter than for earlier periods. Whether this counter intuitive result reflects a "real" difference or is simply due to the small sample will only be resolved with further field work and analysis.

The position of a fire scar within an annual tree ring may provide information about local and regional variations in the fire regime. In particular, "a compilation of the relative position of many scars can reveal seasonal patterns of fire occurrence at a given site" (Baisan and Swetnam 1990, p. 1562). Based on fire scar position in the Ashland RD samples, the majority (34 or 95%) of scars were found between two rings and are believed to represent the dormant (D) season while the others (2 or 5%) were found in latewood (L) which is thought to represent the late growing season. Although it was hard to distinguish between a latewood and dormant season scar, it seems likely that growth slowed and ceased by late summer. It is possible, of course, that the fires recorded as occurring during dormancy reflect spring, fires but that seems unlikely given the lack of lightening at that time of year. More probably is that in the historic and 20th century records both, the seasonality of the fire scars equates to most fires being ignited and burning in late summer (July – September). This is consistent with the patterns observed in the 20th century fire records kept by federal agencies (Higgins 1984; Clark 1993).

To summarize, a major purpose of this pilot study was to first determine whether there was sufficient physical evidence (i.e., fire scarred trees and tree remnants) of past fires extant in the Ashland Ranger District. The answer to that question appears

to be that there is sufficient evidence, at least in those parts of the ARD that have not experienced large stand replacing fires in the 20th century. After confirming the existence of sufficient physical evidence, related objectives were to develop an initial master dendrochronological record based on cross-dating and to collect a small "judgmental" sample of fire scars to begin development of a fire chronology for ponderosa pine forest of the Ashland RD. A 277 year long master chronology was established and, although it may be refined with further research, it was successfully utilized to develop a preliminary fire chronology based on a relatively small subset of fire scars. Analysis of these fire scars indicate most fires were quite localized, but there may have been a few years when fires were ignited and burned in many parts of the Ashland RD. In addition, fire frequency seems to have ranged between 16 and 18 years, depending on which measurement of central tendency is used. The most surprising result, which may be due to the very small sample, was a fire interval average of 7 years for fires that burned in the 20th century. Finally, it appears from analysis of fire scar positions, that all fires were ignited and burned in the late summer/early fall. All of these measurements, except for the 20th century data, are consistent with those observed in other parts of the northern Great Plains.

PONDEROSA PINE RESTORATION RECOMMENDATIONS

The objectives for this study did not include recommendations for forest restoration in the Ashland Ranger District. However, the principal investigator's ecological research and restoration experience in ponderosa pine forests of the Southwest

and southern Rocky Mountains and observations made in the ARD, prompted some suggestions that might be helpful.

There are a variety of ponderosa pine "restoration" approaches and philosophies being discussed and debated today (Agee 2002; Allen et al. 2002). Some examples are potentially problematic for an ecological restoration point-of-view. For instance, an emphasis on catastrophic fire risk reduction, combined with substantial funding such as provided by the National Fire Plan (USDA and USDI, 2000), can drive ecologically insensitive "restoration projects. Similarly, by focusing on producing economic benefits, forest restoration can end up ignoring sound ecological principles. A balance is needed to provide ecologically meaningful restoration in an affordable context.

Two different and currently popular conceptual models of forest restoration are the "structure" and "process" approaches (Agee 2002, p. 24). The "presettlement" structure approach attempts to restore specific stand structure to conditions that existed just prior to when the natural fire regime ceased to function (Covington 2000; Covington et al 1997). This so-called "Flagstaff model" has been proposed for widespread implementation in the Southwest and other parts of the West, without taking into account the great heterogeneity of ponderosa pine forests (Shinneman and Baker 1997), which may compromise current ponderosa pine ecosystem biodiversity and resilience (Southwest Forest Alliance 2001). On the other hand, the process model generally relies heavily or exclusively on restoring fire to forest ecosystems without considering other restoration approaches. For example, prescribed burning in ponderosa pine forests often "…is of such low intensity that fire kills only a fraction of the smallest trees, thus failing

to meet the fundamental objective of thinning overdense forests" (Arno and Allison-Bunnell 2002

In contrast to the limited and/or "one size fits all" models just described, ecological restoration of ponderosa pine forests might incorporate all or most of the sixteen broad principles recently proposed by Allen et al. (2002):

1. Reduce the threat of crown fire.
2. Prioritize and strategically target treatment areas.
3. Develop site-specific reference conditions.
4. Implement incremental, multiple conservative interventions.
5. Utilize existing forest structure rather than reconstructed tree positions.
6. Restore forest ecosystem composition.
7. Retain trees of significant size or age (usually trees greater than 16" dbh).
8. Consider demographic processes (retain some 20th cent. regeneration pulses).
9. Integrate process and structure (restore fire as a keystone process).
10. Control and avoid using exotic species in restoration.
11. Foster regional heterogeneity at all spatial scales.
12. Protect sensitive communities (e.g., riparian areas).
13. Assess cumulative effects of restoration work.
14. Protect from overgrazing (to restore herbaceous understory).
15. Establish monitoring and research programs.
16. Implement adaptive management

Adoption of as many of these principles as possible is highly recommended. Fire risk reduction could be combined with ecological restoration of ponderosa pine forests in the Ashland District using sequential treatments in various combinations of moderate tree thinning and prescribed low-intensity fires. With the ecological restoration approach to forest management, emphasis should be on "leaving the best and taking the rest" rather than on traditional selective logging which favored "taking the best and leaving the rest." In this kind of ecologically sensitive management:

> The goal is to favor healthy, long-lived trees of the historically dominant species and to remove excessive numbers of trees, including accumulations of small trees. Each time the stand is tended, slash, surface fuels, and ladder fuels are reduced. Some trees are allowed to live indefinitely and become snags. The stand may be reentered every few decades to maintain these desirable conditions, but this will

> often allow commercial harvest as a byproduct of doing the ecologically based treatment. (Arno and Allison-Bunnell 2002, p. 132)

This seems to have been the direction of the proposed Threemile Stewardship Project (ARD, CNF 2002).

To restore low intensity fires in the ponderosa pine forests of the Ashland RD to their presumed pre-EuroAmerican settlement average frequency of 17 years would require frequent, repeated prescribed burns. Recently, strong objections have been raised by Baker and Ehle (2001) to the use of the average years between fires, as documented only between the first and last recorded fire in a sampled tree. Baker and Ehle argue that the time from germination (innermost ring date) to the first scar should also be included in the calculation of the average, for indeed the tree had to reach the age at which if first scarred by "avoiding" a severe fire. Utilizing this additional piece of data would increase the average fire return interval significantly in this and most other studies of fire history in the ponderosa pine forests of the West (Baker and Ehle 2001). This controversy aside, clearly, fires did not occur on each patch of forest every 17 years, for how could the forest regenerate and sustain itself with such a short interval everywhere? Rather than focus just on the average interval for the forest, the maximum range of fire intervals (4-64 years), could be used in various areas of the Ashland Ranger District to increase local ecological diversity. Also, to mimic the "natural" seasonal fire patterns, these burns should ideally occur as close to the late summer as possible. This is challenging, given the current generally dense forest structure and may require mechanical thinning before the reintroduction of fire during the dry summer-fall period.

Reintroduced fire, even though it appears to be low intensity, can also be ecologically destructive, especially in late-successional or old growth ponderosa pine.

Studies done in the 1980s, at the Fort Valley and Long Valley Experimental Forests in the Southwest, by Steven Sackett and colleagues showed that when ponderosa pine forests are burned again, probably for the first time, after many years of fire exclusion, 20 to 50 percent of old growth trees can be lost in a single fuel reduction burn (Harrington and Sackett, 1992: 48-49). This is because, today, with the long absence of fire, total fuel loading in old growth ponderosa can amount to 30 to 70 tons (compared to 2-8 tons in the pre-EuroAmerican settlement situation) of litter and duff. Not surprisingly, with this amount of fuel around the base of an old tree, during burning, extremely high soil temperatures can reach a depth that will cause root death and eventually tree death. Another ecological concern is the loss of snags when there is no fireproofing by mechanical fuel removal.

As a consequence of the experiments done around Flagstaff in the 1980s, Covington and Moore, 1992, p. 94) have recommended that heavy fuels be manually removed from the base of large, old trees before reintroducing burning. Also, where there is little or no old growth left, such as previously logged areas, larger replacement post-settlement trees (incipient old growth) may need protection (Covington and Moore, 1992, p. 94). Given that old growth ponderosa pine seems somewhat rare in Ashland RD and considered to be an endangered ecosystem in the United States (Noss et al. 1994), it seems important that caution is used and all known restoration methods, including manual fuel removal, when reintroducing fire.

CONCLUSIONS

A pilot study conducted between 2003 and 2005, by Prescott College researchers in the Ashland Ranger District of the Custer National Forest, confirms that fire was a keystone process in at least one vegetation community---ponderosa pine. The results of our studies in the ponderosa pine ecosystems of the ARD confirm with limited data what many forest managers and fire fighters suspected---namely that fires probably tended to burned more frequently, but with less intensity, than they do today. This research clearly supports using prescribed fire and, perhaps, mechanical thinning to return as much as possible to the historical range of natural variability in ponderosa pine (and other) ecosystems of the Ashland RD. However, it is recommended that principles of ecological restoration, such as those described above, should guide vegetation and fire management, and be considered above the expediencies of economics and perceived fire risk. In other words, both structure and process should be restored together in a systematic, integrated fashion in order to reestablish and maintain ponderosa pine ecosystems that are ecologically healthy and resistant to catastrophic crown and stand-replacing fires.

Overall, the objectives for this pilot study were met, some preliminary observations about fire history were made, and it was clearly shown that a lot can be learned about the fire history of the Ashland Ranger District through use of dendroecological and other historical ecology research methods. Stronger conclusions could probably be drawn if the master dendrochronological record were refined with a larger sample and if fire scar sampling was conducted over a much larger area of the Ashland Ranger District, as well as from other forested areas in eastern Montana (e.g.,

the Sioux District). This would not only provide a more complete reconstruction of climate and fire history in the Ashland RD, but would contribute to the effort to better understand the currently inadequately researched climate and fire history of the northern Great Plains. Accomplishment of these additional objectives would, of course, require considerably more funding as well as a much larger and longer effort. Nonetheless, this pilot study clearly demonstrates that a more comprehensive and detailed study of historic natural variability in climate, fire (and probably other disturbances) could be fruitful for both forest science and management in eastern Montana.

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